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**IBM TECHNICAL DISCLOSURE BULLETIN, vol.24, no.5, Oct.1981, N.Y.US, pages 2267-2268; GREEN J.W.: "Manufacturing method for ink jet nozzles"**

(73) Proprietor: **Hewlett-Packard Company**  
**Mail Stop 20 B-O,**  
**3000 Hanover Street**  
**Palo Alto,**  
**California 94304 (US)**

(72) Inventor: **Schantz, Christopher S.**  
**650 Bair Road**  
**Redwood City, CA 94063 (US)**  
Inventor: **Lloyd, William**  
**Court 5N,**  
**203 5-27-20 Koensi-Minami Suginami-ku**  
**Tokyo 166 (JP)**  
Inventor: **Hanson, Eric**  
**431 Bloomfield Road**  
**Burlingame, CA 94010 (JP)**

(74) Representative: **Schoppe, Fritz, Dipl.-Ing.**  
**Patentanwalt,**  
**Georg-Kalb-Strasse 9**  
**D-82049 Pullach (DE)**

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## Description

The present invention generally relates to inkjet printers and, more particularly, to a process for forming a nozzle member of an inkjet printer.

### State of the Art:

Figure 1 shows an example of a conventional printhead for an inkjet printer. The printhead includes a substrate 11, an intermediate layer 14, and a nozzle plate 12. As further shown in the drawing, a nozzle orifice 13 is formed in plate 12 and a vaporization cavity 15 is formed in substrate 11. For convenience of illustration, the drawing shows only one of the orifices 13 and only one of the vaporization cavities 15; however, a complete inkjet printhead includes an array of circular orifices, each of which is paired with a vaporization cavity. Also, a complete inkjet printhead includes means that connect a number of vaporization cavities to a single ink supply reservoir.

As further shown in Figure 1, a heater resistor 16 of the thin-film type is mounted on substrate 11 and is positioned generally centrally within vaporization cavity 15 such that the heater resistor can be seen when the vaporization cavity is viewed from above. In practice, such heater resistors can be formed on a silicon or glass substrate, for example, by sputtering or vapor deposition techniques. Conventional printheads for inkjet printers include one such heater resistor in each vaporization cavity and the heater resistors are connected in an electrical network for selective activation.

In operation of a inkjet printhead such as shown in Figure 1, pulses of electrical energy are directed to selected ones of the heater resistors 16. When a particular heater resistor receives a pulse, it rapidly converts the electrical energy to heat which, in turn, causes any ink immediately adjacent to the heater resistor to form an ink vapor bubble. As an ink vapor bubble expands, it ejects a droplet of ink from the orifice in the nozzle plate above the energized heater resistor. To illustrate such action, Figure 1 shows an ink vapor bubble 17 and an ink droplet 19.

By appropriate selection of the sequence for energizing the heater resistors in an inkjet printhead such as shown in Figure 1, ejected ink droplets can be caused to form patterns on a paper sheet or other suitable recording medium. For example, a pattern of heater resistors can be energized such that the ejected ink drops form images that depict alphanumeric characters.

For inkjet printers, print quality depends upon the physical characteristics of the nozzles in a printhead. For example, the geometry of the orifice nozzles in a printhead affects the size, trajectory,

and speed of ink drop ejection. In addition, the geometry of orifice nozzles in a printhead can affect the flow of ink supplied to vaporization chambers and, in some instances, can affect the manner in which ink is ejected from adjacent nozzles.

Nozzle plates for inkjet printheads often are formed of nickel and are fabricated by lithographic electroforming processes. One example of a suitable lithographic electroforming processes is described in United States Patent No. 4,773,971. In such processes, the orifices in a nozzle plate are formed by overplating nickel around pillars of photoresist.

Such electroforming processes for forming nozzle plates for inkjet printheads have several shortcomings. One shortcoming is that the processes require delicate balancing of parameters such as photoresist and plating thicknesses, pillar diameters, and overplating ratios. Another shortcoming is that the resulting nozzle plates usually are brittle and easily cracked. Still another shortcoming is that such electroforming processes inherently limit design choices for nozzle shapes and sizes.

When using electroformed nozzle plates and other components in printheads for inkjet printers, corrosion can be a problem. Generally speaking, corrosion resistance of such nozzle plates depends upon two parameters: ink chemistry and the formation of a hydrated oxide layer on the electroplated nickel surface of a nozzle plate. Without a hydrated oxide layer, nickel may corrode in the presence of inks, particularly water-based inks such as are commonly used in inkjet printers. Although corrosion of nozzle plates can be minimized by coating the plates with gold, such plating is costly.

Yet another shortcoming of electroformed nozzle plates for inkjet printheads is that the completed printheads have a tendency to delaminate during use. Usually, delamination begins with the formation of small gaps between a nozzle plate and its substrate. The gaps are often caused by differences in thermal expansion coefficients of a nozzle plate and its substrate. Delamination can be exacerbated by ink interaction with printhead materials. For instance, the materials in an inkjet printhead may swell after prolonged exposure to water-based inks, thereby changing the shape of the printhead nozzles.

Even partial delamination of a nozzle plate of an inkjet printhead can be problematical. Partial delamination can, for example, reduce the velocity of ejected ink drops. Also, partial delamination can create accumulation sites for air bubbles that interfere with ink drop ejection. Moreover, partial delamination of a nozzle plate usually causes decreased and/or highly irregular ink drop ejection velocities.

EP-A-0367541 discloses a method for manufacturing an ink jet recording head. The recording head comprises an outer frame constituting a liquid chamber, a substrate consisting of glass, an energy generating member to be utilized for discharging ink and an ink channel wall defining an ink channel. The recording head portion further comprises a top cover defining a channel structure together with the above described parts of the recording head. At a front side of the recording head, an orifice plate is provided which extends in a vertical direction relative to the main planes of the substrate and the cover. In one embodiment, the orifices are formed by irradiating an excimer laser light on the discharge opening plate or nozzle plate.

IBM Technical Disclosure Bulletin, Volume 25, No. 5, October 1981, pages 2267 and 2268 discloses a manufacturing method for manufacturing ink jet nozzles by feeding a strip through a punch station which places alignment holes in the strip. A small aperture intermediate of each of the alignment holes is punched to form an orifice hole. The strip is then rewound at a rewind station to form a roll of rewound stock material which then may be placed upon a fabricating line. In the fabricating line, which comprises a welding station and a cutting station, a nozzle is moved relative to the stock material. The nozzle is pressed against the apertures of the strap and bonded against same.

The invention is based on the object of providing a simplified process for forming a nozzle member.

This object is achieved by a process in accordance with claim 1 and by a process in accordance with claim 2.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be further understood by reference to the following description and attached drawings which illustrate the preferred embodiment. In the drawings:

Figure 1 is a cross-sectional view of a section of an inkjet printhead according to the prior art;

Figure 2 is a cross-sectional view of a section of an inkjet printhead according to the present invention; and

Figure 3 is a cross-sectional view of an alternate embodiment of an inkjet printhead in accordance with the present invention.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 2 shows an inkjet printhead, generally designated by the number 20, including a polymer nozzle plate 23 laminated to an intermediate layer 25. Although the inkjet printhead of Figure 1 has

somewhat the same appearance as the inkjet printhead of Figure 2, the latter printhead is different in that it is formed of a polymer material that has been photo-ablated or photo-etched. The polymer material preferably is a plastic such as teflon, polyimide, polymethylmethacrylate, polyethyleneterephthalate or mixtures thereof.

In practice, various conventional techniques can be employed for photo-ablating or photo-etching the polymer nozzle plate of Figure 2. Acceptable techniques include, for instance, an ablation process using a high-energy photon laser such as the Excimer laser. The Excimer laser can be, for example, of the F<sub>2</sub>, ArF, KrCl, KrF, or XeCl type.

One particular example of a photo-ablation technique for forming the nozzle plate 23 of Figure 2 is reel-to-reel photo-ablation. In such a process, a strip of polymer film is unreeled under a laser while a metal lithographic mask is interposed between the film and the laser for defining areas of the film that are to be exposed for photo-degradation (i.e., photo-ablation) and areas that are not to be exposed. In practice, the metal lithographic mask preferably is physically spaced from the film during ablation.

Photo-ablation processes have numerous advantages as compared to conventional lithographic electroforming processes for forming nozzle plates for inkjet printheads. For example, photo-ablation processes generally are less expensive and simpler than conventional lithographic electroforming processes. In addition, by using photo-ablation processes, polymer nozzle plates can be fabricated in substantially larger sizes (i.e., having greater surface areas) and with nozzle geometries (i.e., shapes) that are not practical with conventional electroforming processes. In particular, unique nozzle shapes can be produced by making multiple exposures with a laser beam being reoriented between each exposure. Also, precise nozzle geometries can be formed without process controls as strict as are required for electroforming processes.

Another advantage of forming nozzle plates by photo-ablating polymers is that the nozzle plates can be fabricated easily with ratios of nozzle length (L) to nozzle diameter (D) greater than conventional. In the preferred embodiment, the L/D ratio exceeds unity. One advantage of extending a nozzle's length relative to its diameter is that orifice-resistor positioning in a vaporization cavity becomes less critical. Another advantage of nozzles with greater L/D ratios is that such nozzles have less tendency to "gulp" air bubbles into the vaporization cavities during operation of the inkjet printhead.

In use, photo-ablated polymer nozzle plates for inkjet printers also have characteristics that are superior to conventional electroformed nozzle

plates. For example, photo-ablated polymer nozzle plates are highly resistant to corrosion by water-based printing inks. Also, photo-ablated polymer nozzle plates are generally hydrophobic. Further, photo-ablated polymer nozzle plates are relatively compliant and, therefore, resist delamination. Still further, photo-ablated polymer nozzle plates can be readily fixed to, or formed with a polymer substrate.

Figure 3 shows an alternate embodiment of an inkjet printhead of the type including a polymer photo-ablated nozzle plate. In this embodiment, the inkjet printhead is designated as 20A and the nozzle plate is designated as 31. As in the above-described embodiments, a vaporization cavity (designated by the number 33) is defined by the nozzle plate 31, by a substrate 34, and by an intermediate layer 35. Also as in the above-described embodiments, a heater resistor 37 of the thin-film type is mounted in the vaporization cavity. In contrast to the above-described embodiments, however, heater resistor 37 is mounted on the undersurface of nozzle plate 31, not on substrate 34.

At this juncture, it can be appreciated that the above-described vaporization cavities can also be formed by photo-ablation. More particularly, vaporization cavities of selected configurations can be formed by placing a metal lithographic mask over a layer of polymer and then photo-degrading the polymer layer with the laser light in the areas that are unprotected by the lithographic mask. In practice, the polymer layer can be bonded to, or otherwise formed adjacent to, a nozzle plate.

The foregoing has described the principles, preferred embodiments and modes of operation of the present invention. However, the invention should not be construed as being limited to the particular embodiments discussed. The above-described embodiments should be regarded as illustrative rather than restrictive, and it should be appreciated that variations may be made in those embodiments by workers skilled in the art without departing from the scope of present invention as defined by the following claims.

#### Claims

1. A process for forming a nozzle member (31,35) for an ink printer, comprising the steps of:
  - forming a nozzle orifice (36) in a first layer (31) of polymer by photo-ablation;
  - forming a vaporization cavity (33) in a second layer (35) of polymer by photo-ablation;
  - bonding the first layer (31) to the second layer (35);

- attaching a heater resistor (37) to a surface of the first layer (31) facing the vaporization cavity; and
- attaching a substrate (34) to the second layer (35).

2. A process for forming a nozzle member (31,35) for an ink printer, comprising the steps of:

- forming a nozzle orifice (36) in a first layer (31) of polymer by photo-ablation;
- forming a vaporization cavity (33) in a second layer (35) of polymer by photo-ablation;
- bonding the first layer (31) to the second layer (35);
- attaching a heater resistor to a substrate; and
- attaching the substrate (34) to the second layer (35).

3. The process of claim 1 or 2, wherein the photo-ablated polymer comprises a plastic material.

4. The process of claim 3, wherein the photo-ablated polymer comprises teflon, polyimide, polymethylmethacrylate, polyethyleneterephthalate, or mixtures and combinations thereof.

5. The process according to claim 1 or 2, wherein the photo-ablated vaporization cavities (33) are formed in the second layer (35) by placing a metal lithographic mask over a layer of polymer and then photo-degrading the polymer layer with the laser light in the areas that are unprotected by the lithographic mask.

#### Patentansprüche

1. Ein Verfahren zum Bilden eines Düsenbauglieds (31, 35) für einen Tintendrucker, das folgende Schritte aufweist:
  - Bilden einer Düsenöffnung (36) in einer ersten Polymerschicht (31) durch Photo-Ablation;
  - Bilden eines Verdampfungshohlraums (33) in einer zweiten Polymerschicht (35) durch Photo-Ablation;
  - Verbinden der ersten Schicht (31) mit der zweiten Schicht (35);
  - Befestigen eines Heizwiderstands (37) auf einer Oberfläche der ersten Schicht (31), die dem Verdampfungshohlraum zugewandt ist; und
  - Befestigen eines Substrats (34) an der zweiten Schicht (35).

2. Ein Verfahren zum Bilden eines Düsenbauglieds (31, 35) für einen Tintendrucker, das folgende Schritte aufweist:
    - Bilden einer Düsenöffnung (36) in einer ersten Polymerschicht (31) durch Photo-Ablation; 5
    - Bilden eines Verdampfungshohlraums (33) in einer zweiten Polymerschicht (35) durch Photo-Ablation;
    - Verbinden der ersten Schicht (31) mit der zweiten Schicht (35); 10
    - Befestigen eines Heizwiderstands auf einem Substrat; und
    - Befestigen des Substrats (34) an der zweiten Schicht (35). 15
  3. Das Verfahren gemäß Anspruch 1 oder 2, bei dem das Photo-ablatierte Polymer ein Kunststoffmaterial aufweist. 20
  4. Das Verfahren gemäß Anspruch 3, bei dem das Photo-ablatierte Polymer Teflon, Polyimid, Polymethylmethacrylat, Polyethylenterephthalat oder Gemische oder Kombinationen derselben aufweist. 25
  5. Das Verfahren gemäß Anspruch 1 oder 2, bei dem die Photo-ablatierten Verdampfungshohlräume (33) durch Plazieren einer metallischen lithographischen Maske über einer Polymerschicht und dann Photo-Abtragen der Polymerschicht mit dem Laserlicht in den Bereichen, die von der lithographischen Maske nicht geschützt sind, in der zweiten Schicht (35) gebildet werden. 30 35
- formation d'un orifice de gicleur (36) dans une première couche (31) d'un polymère par photo-ablation ;  
 formation d'une cavité de vaporisation (33) dans une seconde couche (35) d'un polymère par photo-ablation ;  
 liaison de la première couche (31) à la seconde couche (35) ;  
 fixation d'une résistance chauffante au substrat ; et  
 fixation du substrat (34) à la seconde couche (35).
3. Procédé selon la revendication 1 ou 2, dans lequel le polymère ayant subi une photo-ablation est constitué par une matière plastique.
  4. Procédé selon la revendication 3, dans lequel le polymère ayant subi une photo-ablation est constitué par un téflon, un polyimide, un polyméthylméthacrylate, un polyéthylénéthéréphthalate ou des mélanges et des combinaisons de ceux-ci.
  5. Procédé selon la revendication 1 ou 2, dans lequel les cavités de vaporisation ayant subi une photo-ablation (33) sont formées dans la seconde couche (35) en plaçant un masque lithographique en métal sur une couche d'un polymère puis en photodégradant la couche de polymère à l'aide de la lumière laser dans les zones qui sont non protégées par le masque lithographique.

## Revendications

1. Procédé de formation d'un élément de gicleur (31, 35) pour une imprimante à encre, comprenant les étapes de :
  - formation d'un orifice de gicleur (36) dans une première couche (31) d'un polymère par photo-ablation ;
  - formation d'une cavité de vaporisation (33) dans une seconde couche (35) d'un polymère par photo-ablation ; 45
  - liaison de la première couche (31) à la seconde couche (35) ;
  - fixation d'une résistance chauffante (37) à une surface de la première couche (31) qui fait face à la cavité de vaporisation ; et 50
  - fixation d'un substrat (34) à la seconde couche (35). 55
2. Procédé de formation d'un élément de gicleur (31, 35) pour une imprimante à encre, comprenant les étapes de : 5

